PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

LACEY et al.

Serial No.: 10/661,528 Group Art Unit: 3661

Filed: September 15, 2003

For: METHOD AND SYSTEM FOR GUIDING A VEHICLE

CLAIM TO PRIORITY

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

The benefit of the filing date of the prior foreign application filed in the following foreign country(ies) is hereby requested and the right of priority provided in 35 U.S.C. §119 is hereby claimed:

Ireland Application No. 2001/0267 filed 16 March 2001.

In support of this claim, filed herewith is a certified copy of said foreign application.

Respectfully submitted,

JACOBSON HOLMAN PLLC

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Atty. Docket No.: P69139US0
Date: April 28, 2004
JCH:crj

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Patents Office
Government Buildings
Hebron Road
Kilkenny

I HEREBY CERTIFY that annexed hereto is a true copy of documents filed in connection with the following patent application:

Application No.	2001/0267
Date of Filing	16 March 2001
Applicant	HAPTICA LIMITED, an Irish company of The Tower, Trinity Enterprise Centre, Pearse Street, Dublin 2, Ireland.

Dated this 11th day of March 2002.

An officer authorised by the
Controller of Patents, Designs and Trademarks.

FORM NO. 1

0 1 0 2 6 7

REQUEST FOR THE GRANT OF A PATENT

PATENTS ACT, 1992

The Applicant(s) named herein hereby request(s)

X the grant of a patent under Part II of the Act

______ the grant of a short-term patent under Part III of the Act

on the basis of the information furnished hereunder.

1. Applicant(s)

Name Haptica Limited

Address The Tower
Trinity Enterprise Centre
Pearse Street
Dublin 2
Ireland

Description/Nationality

An Irish company

2. Title of Invention

"A method and system for assisting an operator to manoeuvre a vehicle in a confined space"

3. Declaration of Priority on basis of previously filed application(s) for same invention (Sections 25 & 26)

Previous filing date	Country in or for which filed	Filing No.

4. Identification of Inventor(s)
Name(s) of person(s) believed by Applicants(s) to be the inventor(s)

LACEY, Gerard
an Irish citizen of 26 Churchgate, Wicklow Town, County Wicklow, Ireland

MacNAMARA, Shane
an Irish citizen 343 Ryevale Lawns, Leixlip, County Kildare, Ireland

5. Statement of right to be granted a patent (Section 17(2) (b)

The Applicant derives the rights to the Invention by virtue of two Deeds of Assignment dated March 1, 2001

6. Items accompanying this Request – tick as appropriate

(i)	X	prescribed filing fee (£100.00)
(ii)	X	specification containing a description and claims
		specification containing a description only
	X	Drawings referred to in description or claims
(iii)		An abstract
(iv)		Copy of previous application (s) whose priority is claimed
(v)		Translation of previous application whose priority is claimed
(vi)	X	Authorisation of Agent (this may be given at 8 below if this Request is signed by the Applicant (s)

7. Divisional Application (s)

The following information is applicable to the present application which is made under Section 24 –

Earlier Application No: ....

Filing Date: ....

8. Agent

The following is authorised to act as agent in all proceedings connected with the obtaining of a patent to which this request relates and in relation to any patent granted -

Name	Address
John A. O'Brien & Associates	The address recorded for the time being in the Register of Patent Agents, and currently Third Floor, Duncairn House, 14 Carysfort Avenue, Blackrock, Co. Dublin, Ireland.

9. Address for Service (if different from that at 8)

As above

Signed ______ JOHN A. O'BRIEN & ASSOCIATES

Date March 16, 2001

APPLICATION No. 010267

"A method and system for assisting an operator to manoeuvre a vehicle in a confined space"

Introduction

The invention relates generally to control of vehicle movement in confined spaces. The vehicle may, for example, be an automobile, a boat, a wheelchair, a walker, a rollator, or a submersible.

Heretofore, the developments in the field of movement control has been on the basis of the vehicle being an autonomous robot. This involves modelling uncertainty arising from only wheel/actuator slip or sensor error. It does not take into account the human aspect whereby a person is actually controlling vehicle movement and requires assistance. An example is an injured or elderly person using a walker or a person manoeuvring a vehicle but has restricted view of the situation.

The invention addresses this problem.

Statements of Invention

According to the invention, there is provided a method for guiding movement of a vehicle controlled by a human operator, the method comprising the steps of:-

planning a path for the vehicle movement;

monitoring vehicle movement; and

generating feedback for the operator to guide movement along the path.

In one embodiment, the method comprises the further step of modelling operator response characteristics to ensure accurate path planning and assist with generating the feedback.

In another embodiment, the method comprises the further step of modelling vehicle movements to assist with generating the feedback.

In a further embodiment, the method comprises the further step of building a map of the space around the vehicle to assist with generating the feedback.

In one embodiment, the path plan is defined as a target of reaching a goal position.

In another embodiment, there are a plurality of sub-goals relating to intermediate positions along the path.

In a further embodiment, each sub-goal is achieved with a single type of vehicle motion.

In one embodiment, operator model and vehicle model parameters are learned during operation of the system.

In another embodiment, an operator's capabilities are used for planning the path.

According to another aspect, the invention provides a control system comprising means for guiding movement of a vehicle in a method as claimed in any preceding claim.

Detailed Description of the Invention

The invention will be more clearly understood from the following description of some embodiments thereof, given by way of example only with reference to the accompanying drawings in which:-

Fig. 1 is a diagram illustrating in schematic form a vehicle start position, path, and goal position;

Figs. 2 to 6 are a sequence of diagrams illustrating progress of the vehicle; and

Fig. 7 is a flow chart illustrating operation of the control system.

Referring to Fig. 1, a vehicle is moved by an operator from a start position to a goal position along a path as indicated with assistance from a guidance system. The guidance system comprises sensors, which may be laser range finders, or computer vision systems. The system builds a map in real time of the space around the vehicle using inputs from the sensors. The sensor outputs are also used to monitor progress of the vehicle. The system also models the particular operator's response characteristics including response times. Thus, the system dynamically builds:

a map of the space around the vehicle,

an operator model of operator response characteristics, and

a vehicle model of vehicle motion.

These are used to plan a path consisting of a number of path segments to a goal position, the latter being inputted by the operator.

The system also comprises an output interface such as a voice synthesiser, audible tones, a display device, or a tactile feedback device. The output interface is used to provide feedback to the operator.

The path segments each complete sub-goals by the operator executing a series of moves in sequence. The moves may be forward, reverse, rotational, or curved moves. Referring to Figs. 2 to 6 a sequence of five sub-goals are achieved to arrive at the goal position in the drawings.

Planned manoeuvres are composed of a path segments. The complexity of the path segments is matched to the operator's ability: in some cases the path segments may be straight line motions inter-connected by on-the-spot rotations or may be a series of interconnected curves.

Goal Definition

Before any planning can take place, a goal that was both reachable and recognisable had to be defined. The operator may indicate the goal to the system by means of some computer input. Alternatively the goal for the manoeuvre may be inferred by analysing the map. Where the vehicle is already within a confined space the objective is assumed to be to join up with the path followed by the vehicle prior to its current pose.

Where parallel parking is the objective the operator can indicate the side of the vehicle that parking should be attempted. The map building process commences and constructs a map of the parking space. The computer system advises the operator on the feasibility of parking in the space and indicates where the automobile should stop. The computer system analyses the map to identify the goal (parked) position of the automobile and plans the path to get to that position.

Dealing with Uncertainty

The planner accounts for the uncertainty in vehicle motion caused by errors produced by the sensors and the operator by calculating bounded regions called the sub-goal regions that the operator is certain to be able to achieve if behaving as normal. For each point in the sub-goal region there exists a set of feasible path segments that when executed will reach the goal or enter a successive sub-goal region closer to the goal.

The accuracy of the human-machine system cannot meet high tolerances, therefore the goal trajectory is calculated to compensate for the accuracy attainable by the operator as described in the operator model. The model of the operator is used to check that the operator is operating correctly. If an error is detected the system provides feedback to ensure that the user moves the vehicle to within path boundaries. If the operator does not respond within the modelled time this is also detected as an error and corrective feedback is given.

Referring now to Fig. 7, the guidance method is described in more detail. The operator model uses a number of factors in order to calculate the stopping distance as follows:

- The operator responds to feedback by changing the direction of the vehicle.
- The delay of the operator in responding to a computer feedback is estimated.
- The current speed and direction of the vehicle are used.
- A model of the vehicle dynamics is used to predict the behaviour of the vehicle in response to the stopping, accelerating and turning forces applied.
- The ratio of the stopping force (F_{stop}) to the propulsive force (F_{ss}) is the constant C:

$$F_{stop} = C \times F_{ss}$$

- The vehicle dynamics are assumed to be a damped mass with first order velocity behaviour given by:

$$m\dot{v} + Dv = F(t)$$

where: m is the mass of the vehicle, v is the velocity of the vehicle, $\dot{v}$ is the acceleration of the vehicle and D is the damping coefficient.

For each type of motion suggested by the computer system the operator model calculates the total distance that will be travelled following a command from the computer system. This distance is used to calculate when the command should be given to the operator in order to reach a goal or subgoal and in so doing high accuracy is achieved in the positioning of the vehicle. The following are the equations used for processing for straight line motion:

$$x_{final} = \frac{m}{D}\left[C\left(\ln\left(\frac{C+1}{C}\right)\right) + \tau_{delay} - 1\right] \times v_{ss}$$

where x_{final} is the total distance travelled, and v_{ss} is the velocity before the feedback is given to the user.

For purely angular motion the final angular distance travelled from the time the user feedback, θ_{final}, is given by the following equation:

$$\theta_{final} = \frac{J}{D_{rot}}\left[C\left(\ln\left(\frac{C+1}{C}\right)\right) + \tau_{delay} - 1\right] \times \dot{\theta}_{ss}$$

Where J is the moment of inertia about the centre of rotation of the vehicle, D_{rot} is the rotational damping coefficient and $\dot{\theta}_{ss}$ is the angular velocity of the vehicle.

Some of the coefficients in the equations, J, τ_{delay}, D and D_{rot} are difficult to measure and may change over time. To address this situation the parameters are lumped together and estimated using a least squares fit of training data.

The operator is asked to perform a sequence of experimental manoeuvres at a variety of velocities. The distance travelled following the provision of feedback is measured. The sequence of points relating velocity to distance travelled is fit to a linear model. Outliers are rejected from the data set by examining the residuals of the least squares fit. Points outside the 95% confidence interval were rejected and the linear model was recalculated. τ_{delay} can be explicitly detected as the time between the feedback being provided and the change in direction of the vehicle. This parameter can be used independently to detect those situations where the operator has missed the presentation of the feedback and the feedback must be repeated. Typically a large number of factors used in the planning of the path such as the vehicle dynamics and the operator response times must be learned from the system as it is used.

The invention is not limited to the embodiments described but may be varied in construction and detail.

Claims

1. A method for guiding movement of a vehicle controlled by a human operator, the method comprising the steps of:-

   planning a path for the vehicle movement;

   monitoring vehicle movement; and

   generating feedback for the operator to guide movement along the path.

2. A method as claimed in claim 1, wherein the method comprises the further step of modelling operator response characteristics to ensure accurate path planning and assist with generating the feedback.

3. A method as claimed in claim 1 or 2, wherein the method comprises the further step of modelling vehicle movements to assist with generating the feedback.

4. A method as claimed in any preceding claim, wherein the method comprises the further step of building a map of the space around the vehicle to assist with generating the feedback.

5. A method as claimed in any preceding claim, wherein the path plan is defined as a target of reaching a goal position.

6. A method as claimed in claim 5, wherein there are a plurality of sub-goals relating to intermediate positions along the path.

7. A method as claimed in claim 6, wherein each sub-goal is achieved with a single type of vehicle motion.

8. A method as claimed in any preceding claim, wherein operator model and vehicle model parameters are learned during operation of the system.

9. A method as claimed in any preceding claim, wherein an operator's capabilities are used for planning the path.

10. A method substantially as described with reference to the drawings.

11. A control system comprising means for guiding movement of a vehicle in a method as claimed in any preceding claim.

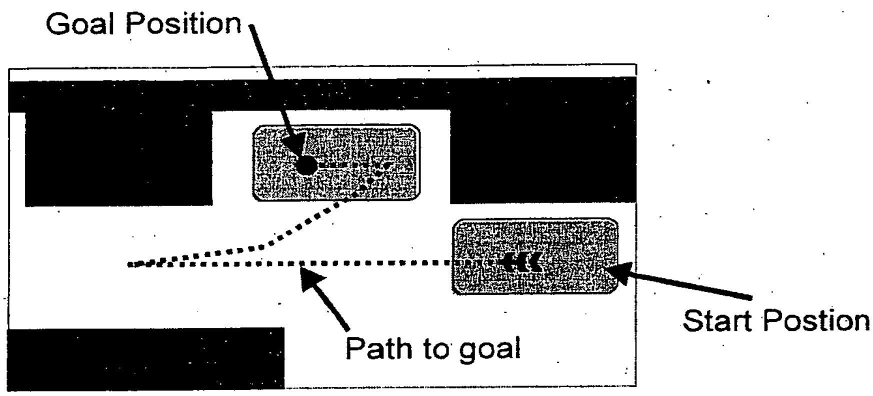

Fig. 1

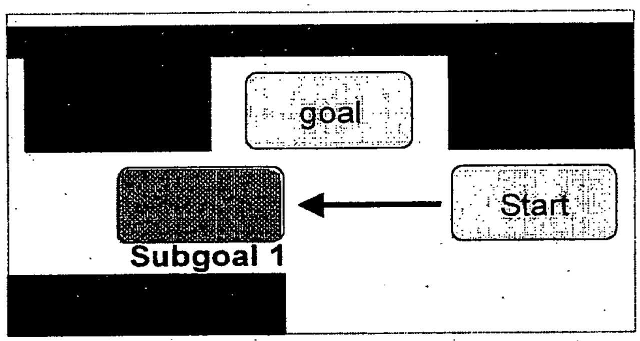

Fig. 2

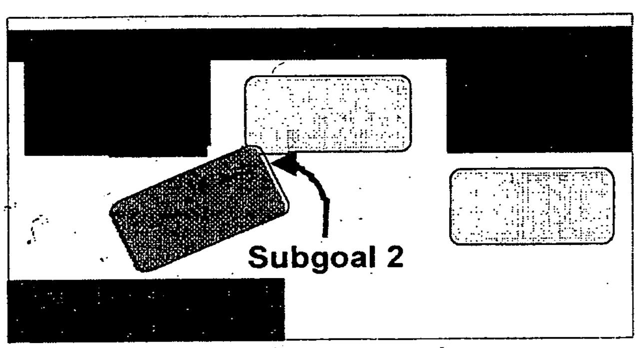

Fig. 3

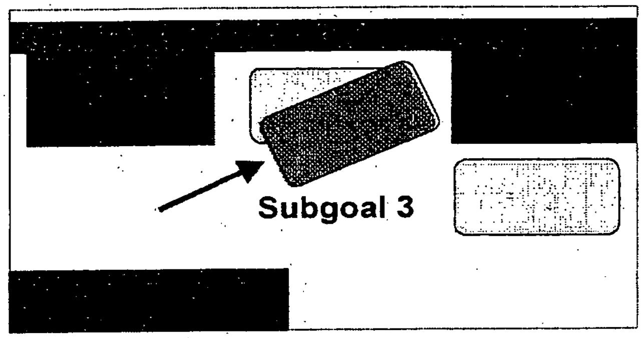

Fig. 4

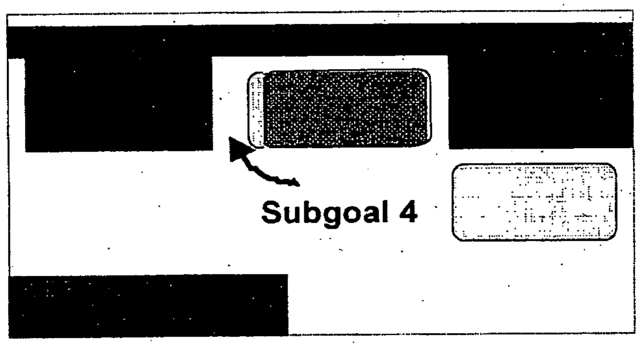

Fig. 5

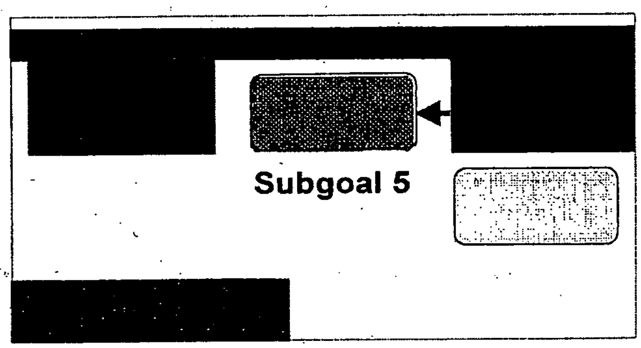

Fig. 6

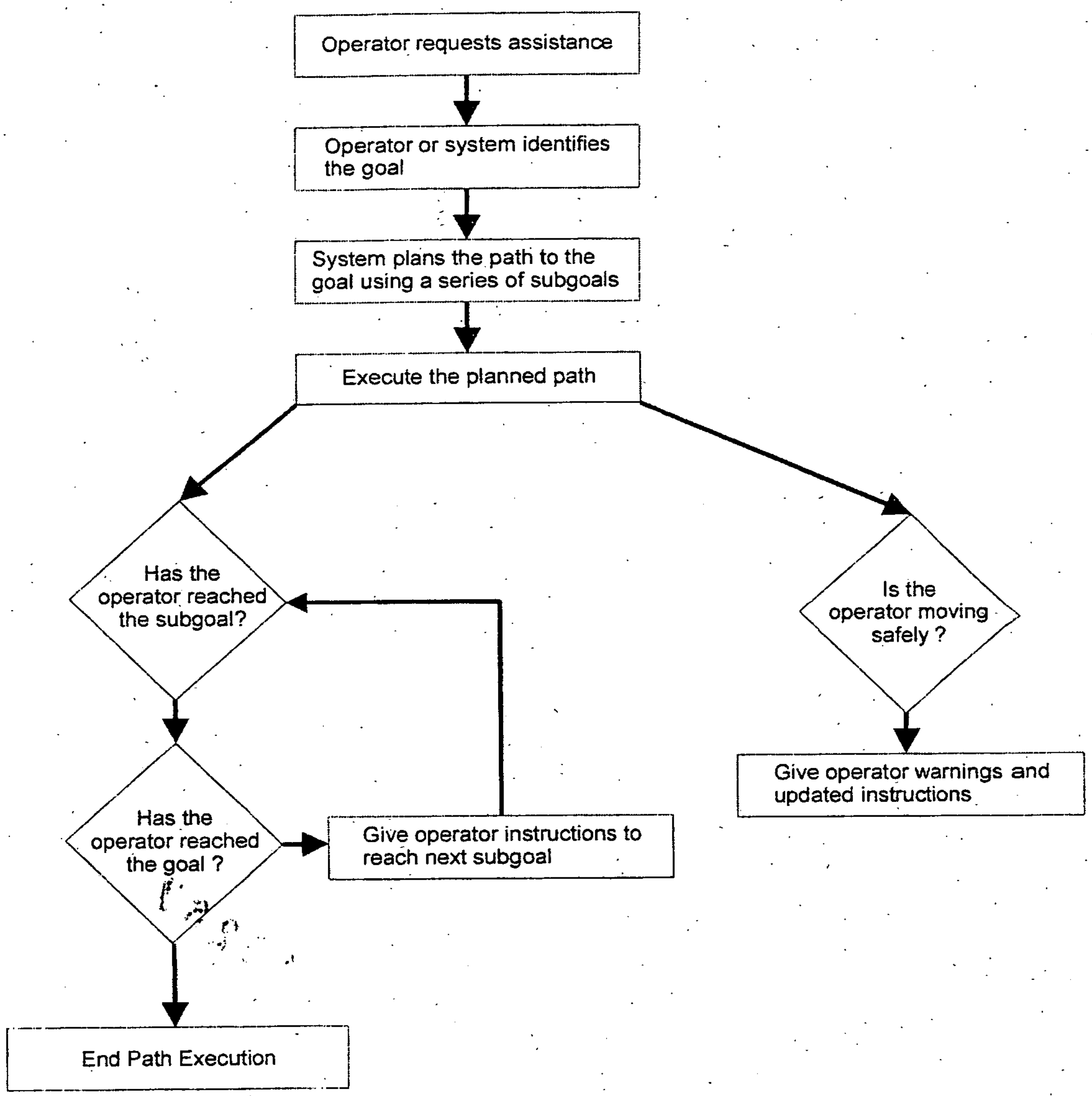
Operator requests assistance
Operator or system identifies the goal
System plans the path to the goal using a series of subgoals
Execute the planned path
Has the operator reached the subgoal?
Is the operator moving safely ?
Has the operator reached the goal ?
Give operator instructions to reach next subgoal
Give operator warnings and updated instructions
End Path Execution

Fig. 7